

Acoustical Technology for the Study of Marine Organisms

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LONG-TERM GOAL

The long-term goal of our research is to improve our ability to observe the ocean's plants, animals and their physical and chemical environment at the critical scales which control how they live, reproduce and die.

OBJECTIVES

Chronic undersampling of the marine environment, including both biological and physical components, has been and remains a major block to understanding how marine ecosystems function and how they respond to changes, whether natural or anthropogenic. Consequently, data-based models that accurately predict local variations in the abundance of plant and animal life in the sea are rare or do not exist at all. Such models would be invaluable in predicting variables such as acoustical and optical scattering in areas of tactical interest to the Navy. Our research directly addresses the root of this problem by attempting to advance acoustical technology as an aid in measuring spatio-temporal distributions of a variety of marine organisms in relation to the physio-chemical ocean environment.

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APPROACH

During the current fiscal year our research was focused in three areas: 1) advancing high-resolution multi-frequency acoustical technology for detecting and observing small zooplankton, micronekton and fish in time and space; 2) the development of a new multi-frequency, multi-static measurement concept, including some fundamental theoretical approaches to aid in remote detection and classification -- with the ultimate long-range objective of remote identification of small organisms in the sea; and, 3) support of other principal investigators in the use of our acoustical zooplankton sensors to carry out several science programs -- most notably the ONR critical scales program focused on thin layers.

WORK COMPLETED

During the last fiscal year we completed the bulk processing for the acoustical volume scattering data from the “thin layers experiment” in East Sound and distributed selected parts of the processed data to several of our co-PIs for use in the preparation of several papers. We took advantage of a break in our sea-going schedule to make hardware and software changes in some of our sensor systems and the programs we use to process and interpret the data. These changes were based on the cumulative experiences we gained during several of our recent coastal zone experiments. We also prepared the instrumentation needed to make multiple frequency scattering strength measurements at multiple azimuthal angles from plankton-size targets with known physical properties and shapes in the laboratory. This was a necessary first step to understanding how to collect, process and interpret multi-frequency, multi-static acoustical data. Some of the early data from this measurement system are discussed below.

RESULTS

We integrated several subsystems and adapted data acquisition software to create a portable acoustical zooplankton system for deployment on the seafloor in shallow water environments of up to about 30 m depth. This system contains a six frequency TAPS which operates in an upward-looking echo sounder mode. It can be deployed autonomously for 2-4 weeks depending on the data collection interval, and has two way UHF telemetry for LOS communications to shore sites at distances of as much as 10–12 nm. It can be connected to a shore-base via a cable at distances of up to 2 km for longer deployments or higher data rates. The system weighs less than 500 lb. including the batteries, sensors, and a protective frame, and is designed to be deployed and retrieved using relatively small vessels in a relatively benign coastal environment. A typical sampling rate is once a minute with a vertical resolution of 12.5 cm. This system is intended to make it practical to routinely monitor small, critical scale zooplankton structures and dynamics in a variety of coastal environments for extended periods.

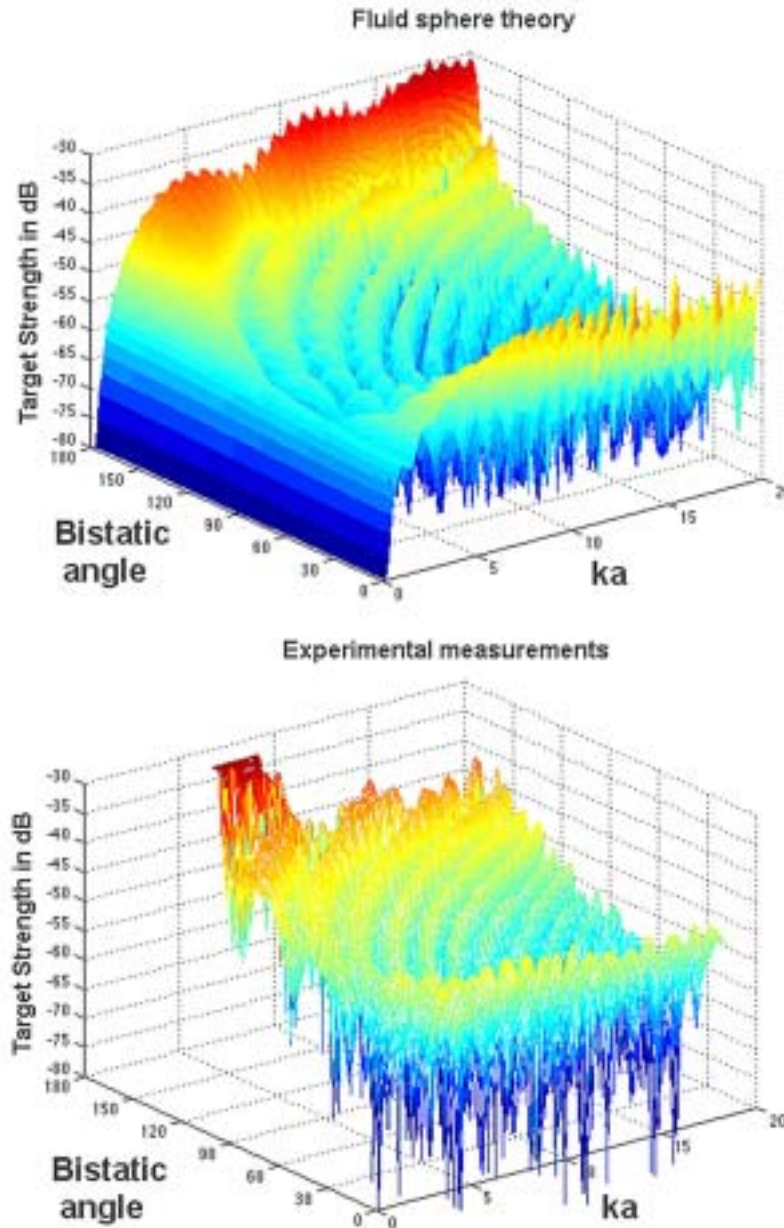


Figure 1: Multi-static, multifrequency target strength data from a small RTV sphere. The top panel represents the theoretical scattering and the bottom illustrates laboratory measurements made to test our experimental technique. The measured data did not extend sufficiently low in frequency to adequately resolve the transition to Rayleigh scattering. In this display, zero degrees is backscattering. Interference between the forward-scattered signal and the direct arrival can be seen near 180 degrees at low ka values. The rippled structure in bistatic angle / ka space contains information about the size, shape and density and compressibility contrasts for the target, which in this case was a 0.9525 mm diameter RTV sphere.

Multi-frequency, multi-static measurements: Modeling results and multi-static scattering measurements (Figure 1) illustrate the complexity of the scattering from even a simple object, in this case an RTV sphere over a wide band of acoustic frequencies. This is a first step in a promising, but undoubtedly challenging process of understanding multi-frequency, multi-static scattering at a level, which will allow its exploitation for zooplankton, micronekton and perhaps fish. Our first attempt at calculating the sphere size involved the use of only one slice of the data from Figure 1, at $ka=8.02$. Those data (Figure 2) were used to calculate the diameter of the sphere, resulting in an estimate that was within 1.5% of the physically measured sphere size, and within the probable error of that measurement. With the use of additional “slices” of the data and measurements of bistatic scattering in additional planes we hope to be able to eventually estimate physical properties (density and compressibility) and target morphologies. The theoretical dependence of a sphere with a diameter of 9.525 mm is superimposed on the measured scattering (Figure 1).

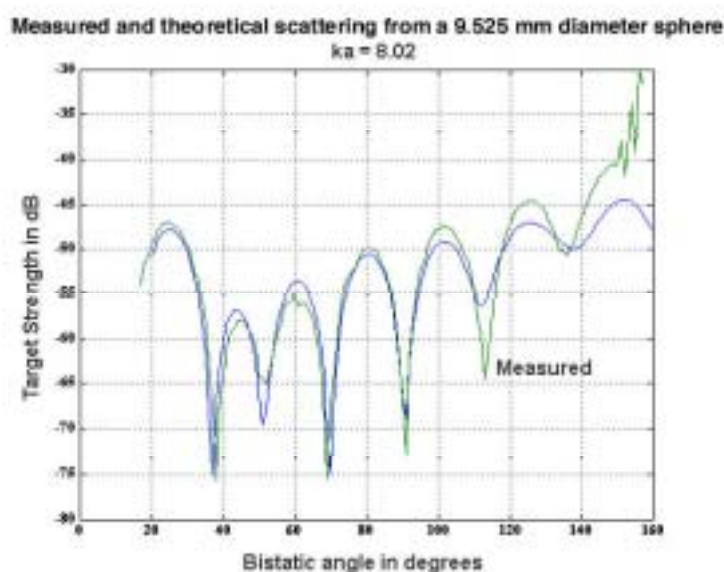


Figure 2: Excellent agreement is shown between the experimental and theoretical target strengths versus the bistatic scattering angle from a 9.525 mm diameter RTV sphere (0 degrees is backscattering). A single slice of data from Fig. 1, at $ka=8.02$ in “non-dimensional frequency space” was “inverted” in “bistatic angle-space, the result being an estimate of 9.41 mm for the sphere diameter. The mismatch between theory and measurement above ca 150 degrees is interference from the direct arrival of the ensonifying pulse.

IMPACT/APPLICATION

Our new measurement package should allow us to examine multiple coastal locations and shallow water marine environments for the presence, duration and even seasonality of numerous critical scale phenomena, such as thin layers, interchanges of biomass between the seabed and the water column. Sampling at resolutions of tens of cm and minutes or better has already revealed details of processes that have not been previously seen. We anticipate that deployment in new places and in different seasons may reveal additional phenomena along with correlated physical and biological forcing.

The multi-frequency, multi-static approach to acoustical scattering promises to stimulate the development of new data-based theoretical modeling approaches for marine organisms. Success in developing this line of research is a step towards remote acoustic classification for marine animals, and in some cases possibly species identification.

TRANSITIONS

We continue to support several other ONR principal investigators (e.g, Percy Donaghay and Jan Rines - URI; Margaret Deksheineks –UCSC; Peter Jumars – U. of Maine; Tim Cowles – OSU; Jim Case and Christy Herren – UCSB; etc.) in the applications of our latest hardware and software developments to their own science programs. We have also been consulting with NOAA’s AFSC (Denise McKelvey) in the application of acoustical technologies to their measurement issues along the Pacific Coast and in the Gulf of Alaska and the Bering Sea. Along with Jim Case and Christy Herren, we participated in the “Spring Break” exercise that dealt with bioluminescence in the San Diego area. We continue to lease zooplankton measurement systems that were based on technology developed with ONR support to a variety of domestic and overseas institutions and agencies, including ORSTOM in France for work in the Equatorial Atlantic and the Mediterranean Sea.

RELATED PROJECTS

Technology developed under this project has been extensively used in the ONR Thin Layers program, the ONR SAX-99 program and in two programs at the University of Maryland’s Horn Point Laboratory (with Mike Roman and Bill Boicourt). One of those programs, both of which dealt with ecosystems research in the Chesapeake Bay, was sponsored by NSF and the other by NOAA.

PUBLICATIONS

Preparation of the following publications depended wholly, or in part, on funding received under this project.

McGehee, D.E., C.F. Greenlaw, D.V. Holliday, and R.E. Pieper. 2000. “Multi-frequency acoustical volume backscattering patterns in the Arabian Sea - 265 kHz to 3 MHz”, J. Acoust. Soc. Am. 107: 193-200.

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Roman, M.R., D.V. Holliday and L.P. Sanford. 2001. “Temporal and spatial patterns of zooplankton in the Chesapeake Bay Turbidity Maximum”. Mar. Ecol. Prog. Ser. 213: 215-227.

Fernandes, P.G., F. Gerlotto, D.V. Holliday, O. Nakken, and E.J. Simmonds. 2000. “Acoustic applications in fisheries science: The ICES Contribution. ICES Symposium on 100 Years of Science under ICES, Helsinki, Finland, August 1-4, 2000.